INFLUENCE OF DLC COATINGS MODIFICATION ON LOAD TRANSFER BY THE GUIDED GROWTH STABILIZATION SYSTEM MODELLING THE SPINE DURING THE AGE OF GROWTH

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Introduction

The current internal stabilization systems of the spine, related to the treatment of scoliosis in children, enable the elimination of the need for multiple operations. The use of kinetic pairs (screw-rod) in the stabilization system makes their relative displacement during the child's growth is possible. The friction between the sliding elements made of titanium alloys contributes to the wear of the material, the particles of which are deposited, among others, in the tissue surrounding the stabilizer and form the so-called “tissue tattoo” [1]. In our research, to eliminate frictional wear, an applied DLC (Diamond-Like Carbon) coatings in kinematic pairs, which, as the research shows, is used as coatings for implants [3]. This material is characterized by high hardness and abrasion resistance, and at the same time, it is biocompatible with tissues.
Our research aimed to evaluate the stabilization components' mechanical properties and friction wear without modification (made of a titanium alloy) and after modification with Diamond-Like Carbon coatings.

Materials and Methods

The research was carried out on spine preparations (Th11-L7) collected from pigs aged 8-10 months and weighing 80÷90 kg. The stabilization system used to follow the growing spine in children SOCORE GGS by NovaSpine consisted of a four-segment stabilization with four central polyaxial screws permanently fixed and with “loose” fixing of the extreme screws (use of movable nuts). The tests also included a stabilization system in which the surface of the rod and the sliding nuts made of Ti-6Al-4V alloy was applied a 1000 nm thick DLC coatings (with the PVD method with CrN interlayer).
To analyse the cooperation of the spine- stabilization system, a long-term cyclic load test using a MTS Bionix® 858 was carried out for 100,000 cycles with a frequency of 1.5 Hz [2]. To assess the wear of the titanium surfaces of the stabilizer elements, tests were carried out on the nuts before and after the operation. The research was carried out using scanning electron microscopy (Jeol JSM 6610A) and an optical profilometer (Leica Filmetrics).

Results and Discussion

Based on the obtained data, the force-displacement characteristics of the tested specimens were determined, which determined the value of the height loss (H) and the stiffness coefficient.
The dynamics of changes in the stiffness coefficient value for the studied groups were similar and characterized by an initial slow increase, lasting up to 80,000 cycles. In subsequent cycles, there was no visible further increase in the stiffness coefficient, and its value in subsequent cycles remained at a similar level.
The modification of the stabilization with the DLC coatings decreased the stiffness by about 6% to the stabilization without the coatings. The *k* value for 100,000 cycles for the spine without the stabilization was 2778 N/mm and was 15% lower than the stabilization without the coatings and 10% lower than the stabilization after modification with the DLC coatings.
The value of the height loss for 100,000 cycles was 8.76±0.62 mm for the stabilization without the coatings, while after modification with the DLC coatings, it was 9.32±1.67 mm.

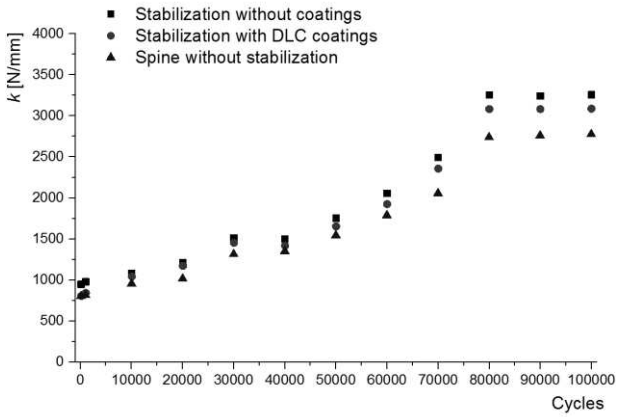

FIG. 1. The average value of the stiffness coefficient (*k*) in subsequent cycles for the studied groups.

The surface friction wear of the nuts was greater in the stabilization without coatings modification than after modification with the DLC coatings. More intense scratches and characteristic abrasions were observed in the places of cooperation between the rod and the movable nut. This results from greater friction of the nuts along the rod (where formed the kinematic knot responsible for the passive "following" effect). This means that the surface of the nuts made of titanium alloys without the DLC coatings was exposed to higher tribological loads during the stabilizer operation.

Conclusions

Based on the conducted long-term cyclic load test, it can conclude that the use of the DLC coatings in the guided growth stabilization system modelling the spine during the age of growth resulted in:
- decreasing the stiffness of the stabilization system,
- increasing the abrasion resistance in kinematic pairs.

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